Understanding and managing interruptions

Katidioti, Ioanna

CHAPTER 1

INTRODUCTION

INTRODUCTION

This chapter has 3258 words. How long does it take to write and revise a text of 3247 words? One working day, eight whole hours of typing and reading, seems more than enough for this amount of text. However, I think no one will find it strange when I admit it took me much more than one day to do it.

When trying to work at my office, it feels as more time is spent talking to colleagues, checking my emails or just browsing aimlessly online than actually writing. When working from home, I avoid colleagues and can turn off email and social media notifications, but I still have to deal with my aimless Internet browsing, my cat wanting to be petted, or my book frequently calling me to read it.

For many people, it may seem impossible to focus on one task for long without being interrupted, either by an external or an internal source. External interruptions are sometimes unavoidable, for example answering the phone might be a required part of your job, even if the call occurs in the middle of writing something. External interruptions can occur at the most inconvenient moments, but there are ways to avoid or at least minimize them, for example by closing your office door or turning off your cellphone. Self-interruptions are harder to manage. You know you should be focusing on your work, but for some reason you keep checking the news website every 10 minutes. To keep self-interruptions under control, more and more people use special apps that block their access to the Internet or they time themselves (e.g., in the pomodoro method you work for a specific amount of time before taking a break) in order to reduce self-interrupting.

It is clear to most of us that interruptions affect our performance in a negative way. We make more errors, take more time to complete our main task or we even postpone its completion. When asked, most people say that interruptions should be eliminated completely in order to achieve optimal performance. They may even consider locking themselves away in a place without Internet connection until the task is finished. In contrast, in this thesis I will accept interruptions as an unavoidable part of everyday life. Even if I lock myself in a room without Internet connection in order to write this thesis introduction, I will still stare at the wall from time to time wondering what to have for lunch or what I should wear for my thesis defense 4 to 5 months from now. Interruptions will keep happening no matter how much we try to avoid them. Therefore, in this thesis I will try to gain a better understanding of the causes behind interruptions and the best way to manage them.

In the first part of this thesis I will try to discover more about self-interruptions. By means of behavioral and eye-tracking experiments, I will examine how cognitive resource availability (cognitive resources, such as vision, are said to be "available" when they are not used by a task) can affect distractibility and interruptibility. I will answer questions such as: What happens to people's rational self-interrupting behavior when they are faced with a browser delay at a moment that it would not be rational to interrupt their main task? Will they self-interrupt or not? The next step will be to move deeper into studying the effects of cognitive resource availability on distractibility. As their main task gets harder, will people be more or less distracted by a cat video that keeps playing in the periphery of their visual field? Does that answer depend on what kind of task they perform: one that needs more visual resources as it becomes more difficult versus a task that requires more cognitive resources as it becomes more difficult?

The second part of this thesis will compare self-interruptions to external interruptions, by answering questions such as: What happens before a self-interruption? Is there a difference with what happens before an external interruption? Which kind of interruption is more disruptive? Finally, in the third part of this thesis, I will present an interruption management system that makes use of our acquired knowledge by trying to interrupt people during moments that are least disruptive, using pupil dilation as a physiological indicator of those moments.

In this Introduction section, I will first present some background on interruptions, the factors that influence their disruptiveness, and existing theories on interruptions. I will then mention how cognitive resources affect interruptions and how there is a need for experimental studies that directly compare self-interruptions and external interruptions. Finally I will present pupillometry as a research method in cognitive science, a method I used in several of the studies reported in this thesis.

BACKGROUND

Definition of interruptions

Interruptions can be considered as a form of sequential multitasking (see Salvucci & Taatgen, 2011), since the person that is interrupted has to deal with more than one tasks. Figure 1 shows the timeline of interruptions (adapted from Trafton, Altmann, Brock, & Mintz, 2003). First, someone performs a main task, such as writing a thesis introduction.

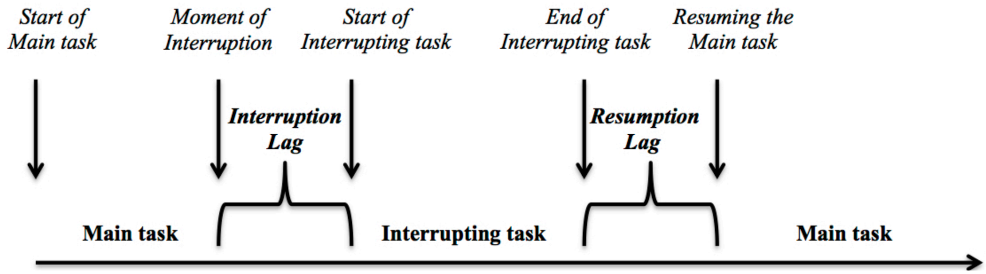


Figure 1.1. *Interruption timeline, based on Trafton et al. (2003)*

An interruption occurs, for example the sound of an incoming email. The time between hearing the sound and opening the email is called the interruption lag. Next, the interrupting task (reading the email) is performed. The time between having read the email and resuming the writing of the introduction is called the resumption lag. Finally the main task is continued.

Trafton et al. (2003) assume on the basis of this timeline that the total cost of interruption is the sum of the interruption lag and the resumption lag (naturally, this is in addition to the time lost to the interruption itself, but that time might be spend effectively on a secondary task). However, there are more factors that could contribute to the disruptiveness of the interruption, such as loss of efficiency after the main task is resumed. In this thesis I will not focus on the resumption lag as a measure of disruptiveness, but I will look at performance on the whole task. Furthermore, I will investigate whether this timeline is also valid for self-interruptions.

Frequency and effects of interruptions

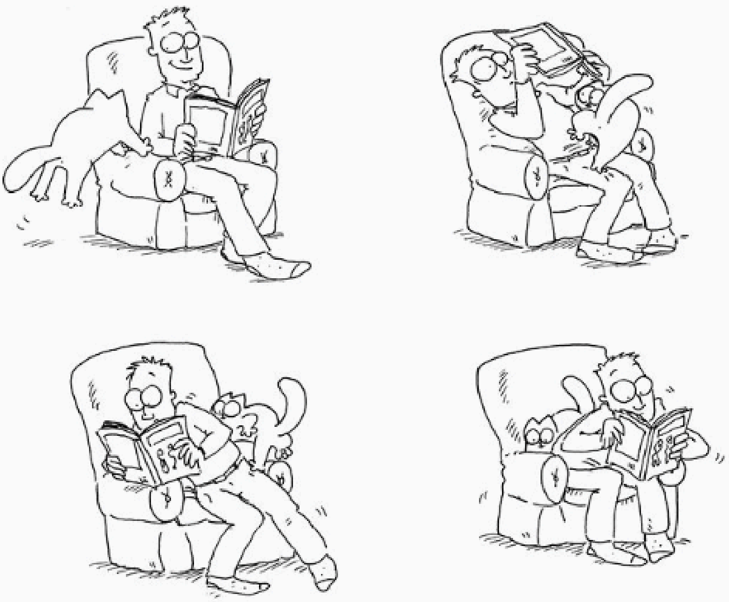
There are more than a few studies that confirm what we all suspect: interruptions happen constantly, with self-interruptions being as frequent as external interruptions. For example, a large observational study revealed that information workers are interrupted every 3 minutes and about half of these interruptions are self-interruptions (Gonzalez & Mark, 2004). Interruptions interfere with important aspects of everyday life, such as working (e.g. Mark, Gonzalez & Harris, 2005) and studying (e.g. Rosen, Carrier, & Cheever, 2013). The main negative effects of interruptions are that the main tasks take more time to be completed and more errors are made (e.g., Monk, Trafton, & Boehm-Davis, 2008; Brumby, Cox, Black & Gould, 2013).

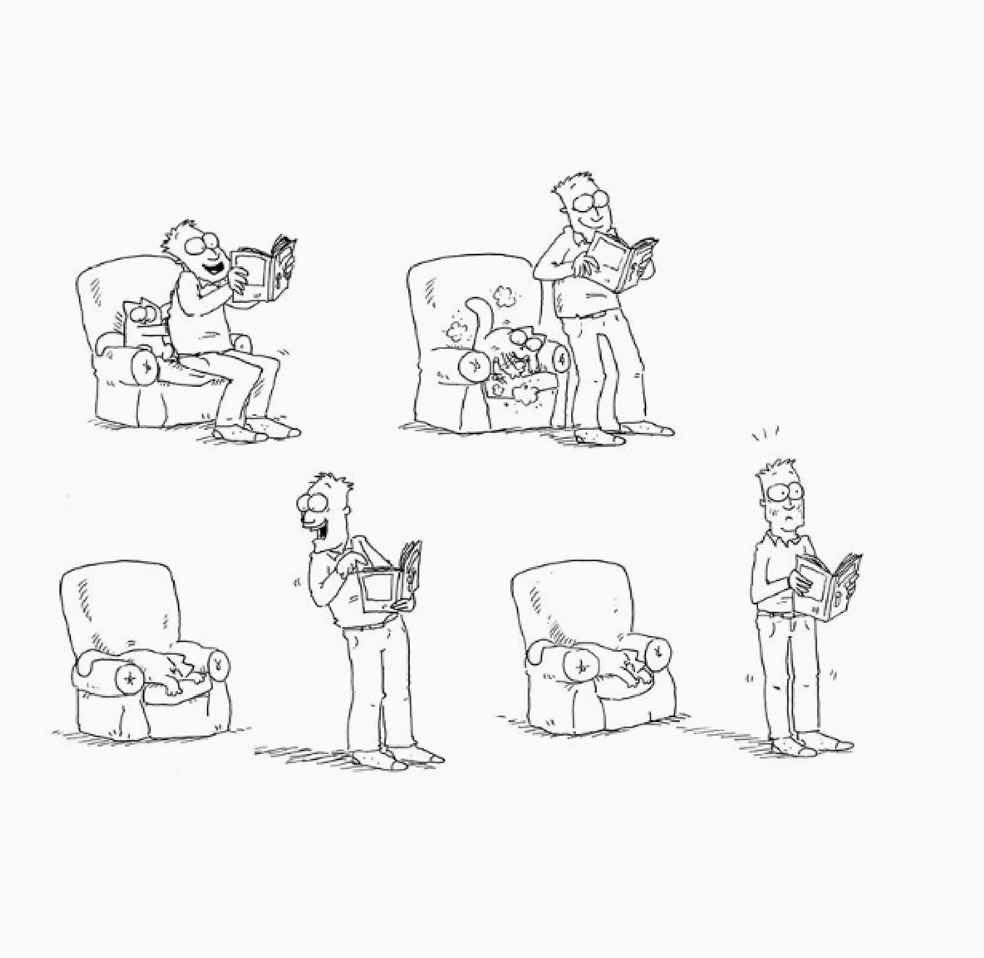
However, the disruptive effect of interruptions varies. There are a number of factors that can make an interruption more or less disruptive. First, long interruptions are more disruptive than short ones (e.g. Gillie & Broadbent, 1989; Monk et al., 2008). Second, complex interrupting tasks are more disruptive than simple ones (e.g. Cades, Boehm-Davis, Trafton & Monk, 2007; Monk et al. 2008). Third, an interrupting task relevant to the main task is less disruptive than an unrelated one (e.g. Czerwinsky, Cutrell, & Horvitz, 2000; Gould, Brumby, & Cox, 2013). Fourth, an alert before the interruption minimizes the resumption lag (e.g. Hodgetts & Jones, 2003, Monk et al. 2008). Finally, the moment that the interruption occurs within the main task affects the level of disruption. An interruption that occurs when the cognitive workload of the task is high (e.g. while in the middle of typing a word) is more disruptive than an interruption during a low-workload moment, such as after finishing a paragraph (e.g. Iqbal & Bailey, 2005; Monk, Boehm-Davis & Trafton, 2004).

Despite all the literature mentioned above, much remains to be discovered about interruptions. One area that has seen little research are self-interruptions: there are very few experiments on self-interruptions and the underlying causes of our constant need to interrupt our work to engage in unnecessary tasks are still unknown. Furthermore, there is the need for a cognitive theory that can provide a satisfactory explanation for all the experimental results mentioned above.

Interruption theories

One of the main theories on interruptions is Memory for Goals (Altman and Trafton, 2002). According to this theory, each task has a goal and an activation level. When the main task is interrupted, its goal is stored in memory and starts to decay, while the interrupting task's goal is activated. Returning to the main task entails resuming its goal. Longer interruptions result in a greater decay of the main task goal and consequently it takes more time to resume the main task after a longer interruption. Although Memory for Goals takes into consideration the effects of the length of the interruption, it does not account for the other factors that affect the disruptive effect of interruptions such as resource availability.





This strip by Simon's Cat© was a low-workload moment interruption

Borst, Taatgen and van Rijn (2015) extended Memory for Goals theory to Memory for Problem States and shifted the focus from goals to problem states (problem state contains the information necessary for the completion of a task). They propose that the main and the interrupting task could have an associated problem state, in which case the interruption is handled as in Memory for Goals: the main task's problem state is stored and starts decaying until the interrupting task is finished. However, if the main or the interrupting task does not require a problem state, the length of the interruption will not affect the resumption lag. With this extension, the factors of interrupting task complexity and moment of the interruption are also taken into account.

Interruption theories are improving, but they still cannot account for all phenomena. One challenge is self-interruptions, probably because they are difficult to evoke in controlled experiments. The results of this thesis will extend our knowledge and theories of interruptions.

Cognitive resource availability and interruptions

In the first part of this thesis I will focus on the effect of cognitive resource availability on self-interruption. Cognition can be divided into separate cognitive resources, such as vision, working memory, motor functions etc. and different tasks make use of different cognitive resources. For example, watching a silent video uses visual resources, while writing the introduction of your thesis uses vision, declarative memory, language processing and motor resources.

It is well known that cognitive resource availability affects multitasking behavior. According to Wickens' Multiple Resources Theory (2002) there is greater interference when one is trying to combine two tasks that share a cognitive resource than when trying to combine two tasks that do not share a resource. People cannot look simultaneously at two things; therefore combining two visual tasks is hard, whereas combining two tasks that do not share a resource (e.g. driving while listening to music) is easy (this is also part of Threaded Cognition theory; Salvucci & Taatgen, 2011).

One of the principles mentioned in Salvucci and Taatgen's Threaded Cognition theory on multitasking (2008; 2011) is the resource usage principle, according to which resources are being used in a greedy, polite manner. That means that if two tasks are competing for the use of a resource, once this resource becomes available from the one task it will be released ("polite") and the other task will use it ("greedy").

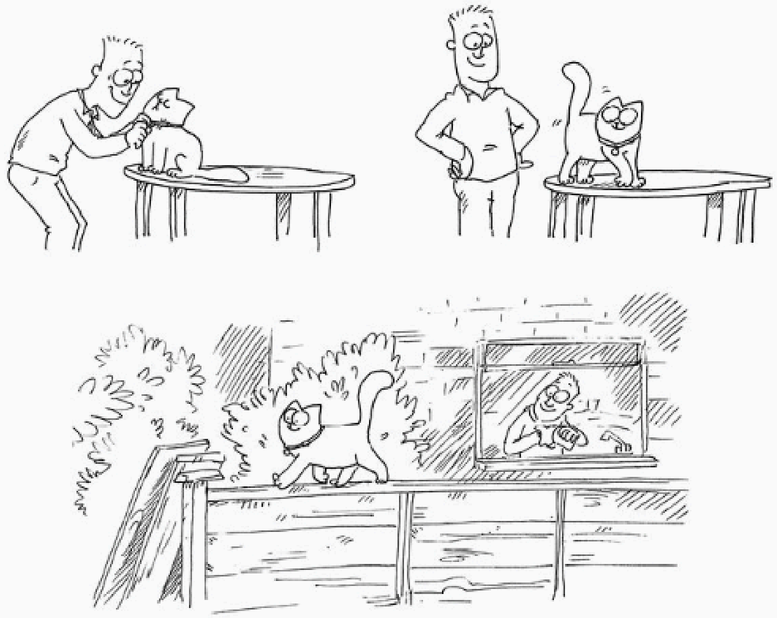
For example, when the silent video you are watching in your browser ends, your visual resources will be occupied by the advertisements on your screen or the suggestions for similar videos. Using the theories of Threaded Cognition (Salvucci & Taatgen, 2011) and Multiple Resources (Wickens, 2002) on self-interruptions, the first part of this thesis turns the logic around, and tries to answer the question: when a cognitive resource becomes available, will that lead to self-interruption?

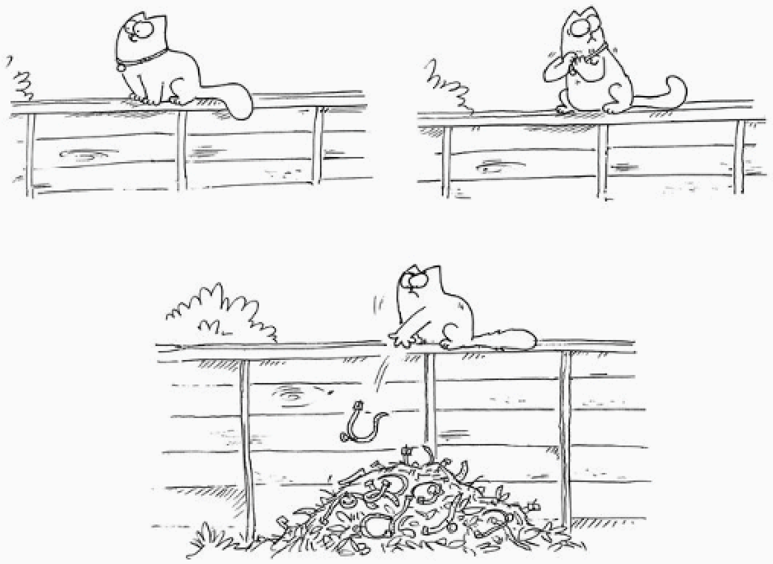
There are experiments that demonstrate the ability of people to self-interrupt rationally (e.g. Salvucci & Bogunovich, 2010). When given the freedom to self-interrupt, people usually chose optimal moments and minimized the negative effects of self-interruptions. However, I hypothesize that once the resources needed by the interruption are available, people will self-interrupt at the wrong moments. I will test this cognitive resources theory by using a visual distraction during two different tasks: one that releases more visual resources as it becomes more difficult and one that uses more visual resources as it becomes more difficult. On the basis of my hypothesis, the prediction is that participants will be more distracted by the visual distractor as the visual resources become more released, even if the main task becomes more difficult.

External vs. self-interruptions

The second part of this thesis will focus on comparing self-interruptions and external interruptions. Although there are many experimental studies showing the negative effects of external interruptions (e.g. Altman & Trafton, 2002; Monk et al., 2008), there are only a few investigating self-interruptions. Although observational studies reveal that self-interruptions are as common and as disruptive as external interruptions (e.g. Dabbish, Mark & Gonzalez, 2011), it is not simple to create an experimental setup for studying them. However, one consistent result of the few existing studies that give participants the freedom to choose their interruption moments (e.g., Payne, Duggan & Neth, 2007) is that people usually behave rational when self-interrupting: People will seldom choose to check their emails whilst in the middle of typing a word. They will wait for the end of a paragraph or a chapter in order to do that and that way they will resume their main task more easily.

There are even fewer studies that compare self-interruptions with external interruptions and even when they do, the design is usually flawed. For example, McFarlane (2002) compared four different kinds of interruptions, three external (immediate, scheduled and using an





This strip by Simon's Cat© was a high-workload moment interruption.

Was it more disruptive than the previous one?

interruption management system) and one negotiated interruption. However, his negotiated interruption was not exactly a self-interruption, since participants were externally interrupted by the interrupting task, but could choose when to act on that interruption. Panepinto (2010) gave participants the freedom to self-interrupt during a Sudoku game, but the external interruptions in her study occurred at random moments. Since participants probably chose the optimal moments to self-interrupt[1] the comparison automatically favors the self-interruptions. However, Panepinto did not find a difference in performance between the two kinds of interruptions. Assuming that forced interruptions occurred on average at more disruptive moments, this suggests that forced interruptions might in fact be preferable over self-interruptions.

In order to compare external and self-interruptions, both kinds of interruptions should occur at similar moments within the task. For that reason, I created a situation in which both external and self-interruptions occurred at the same moments of the main task in Chapter 4 and Chapter 5 of this thesis. I hypothesize that if both interruptions happen on rational moments (when the workload is low), external interruptions will be less disruptive, since they do not require the person to make a decision on when to interrupt themselves.

METHODS

Pupil Dilation

In this thesis I will use changes in pupil dilation as a method to study the effects of interruptions. Pupillometry has been used widely for decades in cognitive science (e.g. Beatty & Lucero-Wagoner, 2000). It is common knowledge that the pupil reacts to light changes, however, many studies show that it reacts to non-visual stimuli as well, such as emotions and cognitive processes. Pupillometry has been used to study Stroop effects, task complexity, workload changes and more (e.g. Laeng, Sirois & Gredeback, 2012). Pupil dilation also reflects some more unexpected cognitive functions, such as uncertainty when gambling (Satterthwaite, Green, Myerson, Parker, Ramaratnam & Buckner, 2007) or suppression of the urge to press a button (Chiew & Braver, 2013).

In this thesis, pupil dilation will be used mainly as a measure

---

1 There is no such mention in Panepinto's paper, but given other studies (e.g., Salvucci & Bogunovich, 2010), it seems natural to assume that.

of cognitive workload[2]. Since the 1960s, there have been many studies showing that pupil dilation increases as the mental workload increases (Kahneman & Beatty, 1966). For example, many studies showed that pupil dilation increases as the number of elements that need to be retained in the working memory increases (e.g. Peavler, 1974; although of course there is a limit to this phenomenon, as Granholm, Asarnow, Sarkin & Dykes, 1996 suggest). There are also different kinds of increases in mental workload that create increases in pupil dilation: mathematical equations (e.g. Hess & Polt, 1964) or language tasks (e.g. Schluroff, 1982) create a bigger increase in pupil dilation as they become more difficult.

Interruption studies have made use of this relation between pupil dilation and cognitive workload. For instance, Iqbal, Adamczyck, Zheng & Bailey (2005) used pupil dilation to identify low-workload moments of a document editing and a route-planning task. In a follow-up study Iqbal & Bailey (2005) used these defined low-workload moments to schedule interruptions and discovered that (as expected) interruptions at low-workload moments are less disruptive than interruptions at high-workload moments. In the interruption management system I present in Chapter 6, I use the fact that pupil dilation decreases at low-workload moments to create less disruptive external interruptions by automatically interrupting users at low-workload moments. This goes beyond previous systems in that it does not require a task analysis.

Furthermore, in Chapter 4 and Chapter 5 I investigate how pupil dilation reacts before a self-interruption and an external interruption, and what that tells us about the difference between external and self-interruptions. In these chapters I use pupil dilation changes mainly to compare the timeline of a self-interruption with that of an external interruption. Pupillometry has been used in many studies in order to identify the different parts of a task (e.g. Hess & Polt, 1964, Iqbal et al., 2005) and is a useful method for finding differences between cognitive reactions.

---

2 To be more precise, what studies refer to as "cognitive/mental workload" would be better described as "processes related to cognitive control". For consistency with past research, we will keep calling it "cognitive/mental workload".

DISSERTATION OVERVIEW

The area of focus of this dissertation is self-interruptions, and it seeks to answer the following questions:

- How does cognitive resource availability affect interruptibility?
- What happens before a self-interruption?
- Are external interruptions more or less disruptive than self-interruptions?
- How can we minimize the negative effects of interruptions?

Part 1 of this thesis focuses on how cognitive resource availability affects interruptibility and consists of Chapter 2 and Chapter 3. In Chapter 2 I present an experiment which questions people's rationality in self-interrupting, by enhancing cognitive resource availability on moments that it is not rational to self-interrupt. In Chapter 3 I discuss the effects of cognitive resource availability on distractibility by presenting an experimental study that compares two tasks that use different cognitive resources.

Part 2 of this thesis focuses on comparing external and self-interruptions and consists of Chapter 4 and Chapter 5. Chapter 4 focuses on the differences between the effects of self-interruption and external interruption on pupil dilation. Chapter 5 again compares self-interruptions and external interruptions in order to replicate the results of Chapter 4 on a different task and confirm which kind of interruption is more disruptive.

Part 3 of this thesis consists of Chapter 6 and describes an interruption management system that tries to interrupt people on optimal moments based on changes in pupil dilation to cognitive workload. Finally, Chapter 7 offers an overview of the results of this thesis and the insights they offer on interruptions.

PART 1

The effects of cognitive resource availability on self-interruptions